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THE ECOLOGICAL RELATIONS OF THE VEGETATION OF WESTERN TEXAS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXX.

WILLIAM L. BRAY.

(WITH TWENTY-FOUR TEXT FIGURES)

[*Concluded from p. 217.*]

SEMI-XEROPHYTIC FOREST OF THE HIGH MOUNTAIN SUMMITS AND WATERED CANONS OF TRANS-PECOS TEXAS.—On the higher Guadalupe and Davis mountains the annual rainfall is several inches greater than the normal for that meridian, and greater than in similar altitudes in the mountains of the Great bend of the Rio Grande. The mean temperature also, because of the northerly position and altitude, is enough lower than in other portions of trans-Pecos Texas to make these mountain summits a distinct zone, namely the Transition zone. On these higher summits and in the well-watered cañons leading down from them, the extreme xerophytic conditions of the region are very much modified. This becomes very evident in the aspect of the prevailing formation, an almost mesophytic forest.

The chief elements of the formation are as follows: *Pinus ponderosa*, on Guadalupe peak at 9000 feet, attains a height of 50 feet, with trunk 2 feet in diameter; on the Davis mountains it has yielded clear lumber 18 inches wide. This is the prevalent species, occurring in places in pure formation, as at the "pinery" northeast of Limpio peak. Next in prevalence is *Pseudotsuga taxifolia*, which attains similar dimensions. *Pinus flexilis* reaches a diameter of scarcely more than a foot. Below there begin *Pinus edulis*, *Juniperus pachyphloea*, and the oaks of the xerophytic slopes. The summit formation descends into the upper cañons a short distance.

In addition to the species just cited, the following transition

species are important elements: *Cercocarpus parvifolius*, *Ribes viscosissimum*, *Fendlera rupicola*, *Frasera speciosa*, *Geranium caespitosum*, *Campanula rotundifolia*, *Heuchera rubescens*, *Artemisia frigida*, and *Acer grandidentata*. A few of these reach the summits of the highest mountains in the Great bend, but scarcely in force enough to change the strongly upper Sonoran character.

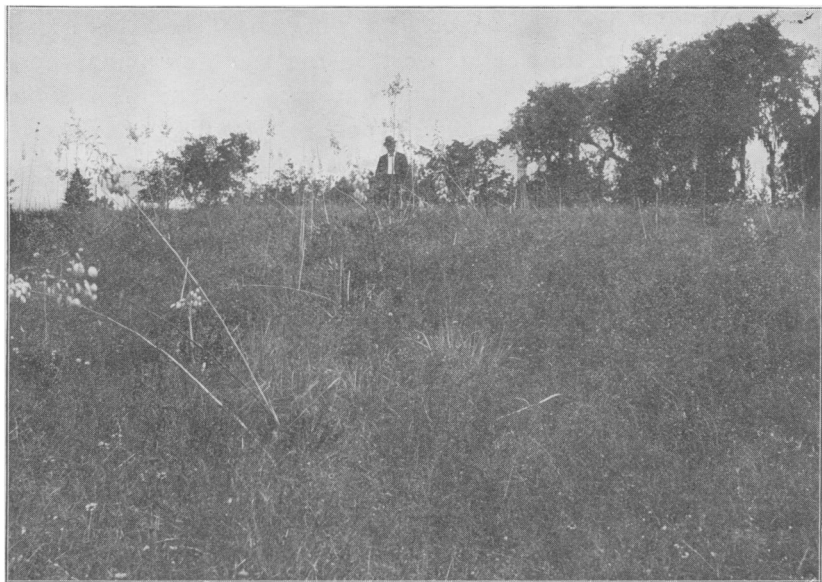


FIG. 14.—Vegetation of adobe slopes and chalk exposures: characteristic of Cretaceous Texas, especially on the Grand prairie and the eastern half of the Edwards plateau.

In the lower cañons, the dwarfed arborescent species of the xerophytic slopes become large trees of regular symmetrical growth. Thus, *Quercus Emoryi* "becomes a straight tree 2 to 4 feet in diameter and 60 feet tall, forming the main feature of the sylva. Here also *Pinus edulis* attains the unusual size of 18 inches in diameter and 40 feet in height" (Havard). These cañons contain in addition numbers of characteristically mesophytic or semi-mesophytic woody species, as species of *Prunus*, *Acer*, *Philadelphus*, and *Fendlera*, while the sides of watered

cañons and the bottoms of dry ones contain those species of the central erosion formation whose range is to the southwest and west. In the main, however, the dry cañons and lower slopes are beset with a chaparral formation, to be discussed separately

XEROPHYTIC AND SEMI-MESOPHYTIC POST OAK FORMATIONS.—The post oak formation furnishes a striking instance of the close relation existing between soil structure and its vegetation covering. Where there are exposures of coarse sand beds and gravelly clays, at least as far west as the 100th meridian, there occurs an arborescent formation whose main elements are the two species of oak *Quercus minor* (post oak) and *Q. Marilandica* (black jack). Very extensive areas of this formation occur also on the western margin of the east Texas forest belt. In the west Texas region the areas are in the main as follows: (1) the extension of Fayette sands into the Rio Grande plain; (2) the gravelly débris and sands of the granitic area and its borders (extending for example westward beyond Fredericksburg); (3) the sands and gravels of the Carboniferous area (Brownwood and Palo Pinto countries); (4) the upper cross timbers (the lower cross timbers to the east of our area are of the same formation); (5) river terrace gravel beds, such as those about Austin.

The character of the formation varies with the underground water conditions. Where the porous textured sand or gravel beds lie so that the soil water level is easily available, the formation is a compact forest with a mixture of semi-mesophytic trees filled in by a lower zone of shrubby species. Such is the character of the formation in the Fredericksburg district and in the upper cross timbers. More frequently, however, the soil water conditions are not so favorable, and as a consequence the formation more nearly reflects the normal climatic conditions, as in the granite country. Then it is no longer a compact forest, but an open timbered grass plain where the trees are of low stature and broad spreading crown, each with the individuality of orchard trees. As a consequence of this open formation, such a forest displays no cooperative capacity in producing

a shaded zone, or in collecting humus materials. This leaves a practically continuous grass floor. It also permits the encroachment of sun loving species of the chaparral formations, notably mesquite. Thus many miles of the granite area are covered with a thick growth of mesquite chaparral, with undergrowth of prickly pear and several woody species of the Rio Grande chaparral.

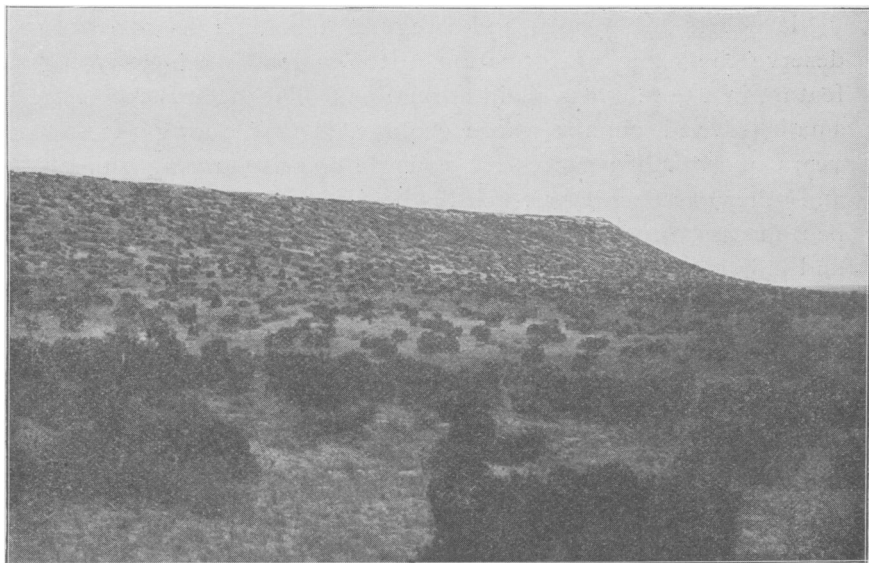


FIG. 15.—*Quercus grisea* and *Juniperus* formations on an outlying butte of the Staked plains, Big springs; common formation on buttes in western part of central provinces.

The post oak formation of the Rio Grande plain is, as suggested, a southwesterly continuation of the timber of the Fayette prairie sands (in reality of the east Texas forest belt). The southwesterly extension of the formation carries it beyond the Nuéces river, but it has been met by a more vigorous expansion of the Rio Grande chaparral, which has covered the plain as far east as the Guadalupe with a dense mesquite jungle and its accompanying undergrowth of prickly pear.

XEROPHYTIC LIVE OAK FORMATION OF THE OPEN GRASS PLAINS.
—That part of Texas lying between the 97th and 100th

meridians, that is the transition from mesophytic to xerophytic zones, is often called the live oak belt because of the characteristic occurrence of *Quercus Virginiana*. The live oak formation of the central erosion area has already been described. This is in reality a part of the live oak belt, but the characteristic occurrence of the live oak throughout its zone is upon the open grass plains of the central region from the Gulf to Red river.

It occurs in so open and irregular a manner as barely to deserve the name of formation. It is in reality a punctuating feature in a pure grass plain formation. The occurrence is in small isolated clumps whose ecology is that during the first years of growth a successful struggle against grazing animals and other encroaching agencies is best waged from these compact masses, which themselves come to have the form of crown and individuality of a single tree. These clumps may be called centers of infection, for by them the species is spreading. Some exceptions to the very open formation occur, as in Live Oak and Bee counties, where the live oak timber becomes a very prominent feature of the landscape.

The species in this zone is very hardy, and attains a great age and large growth. The characteristic growth is expressed in the following dimensions, which though far above the average as to actual size are by no means unusual; diameter of trunk four feet; height of trunk to main branches six to eight feet; total height of tree thirty to forty feet; spread of crown one hundred feet.

MESOPHYTIC FOREST FORMATIONS OF THE STREAMWAYS.—There are two general types of this formation, namely that of the open streamways or broader alluvial river valleys, and that of the enclosed box cañons of the erosion areas.

Timber formations of open streamways.—It happens that, excepting the Rio Grande and Nuéces, the larger rivers rise in regions of very low rainfall, and lead into zones of greater (often heavy) rainfall. It happens, also, that the direction of flow brings them within or accessible to the east Texas forest belt. The result is that the streamways are lines along which

some elements of the forest belt spread into regions far beyond its normal boundaries. Thus, the Red river, Trinity, and Brazos carry purely mesophytic forests to the 97th meridian, and heavy timber far into the central province; and the Colorado, aside from the timber of its cañon course, carries big growths of pecan and sycamore beyond the 101st meridian.

Floristically the streamway formation does not include the

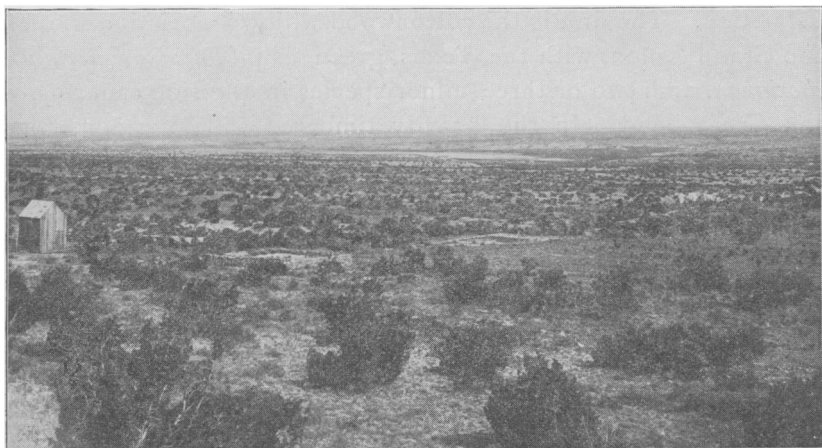


FIG. 16.—Chaparral formation on Staked plains debris, Big springs; a north-eastern extension of the trans-Pecos Sonoran chaparral belt.

species which give the east Texas forest its distinctive character. The pines, gums, magnolia, maple, and water oaks are not present, but on the contrary a selected group of species, which more readily adapt themselves to conditions of the open country, greater exposure to dry winds, greater sunlight, and less available water supply. Such are the hackberry, pecan, sycamore, elms, and some oaks. These species are constant associates in the streamway timber of the prairies. Farther out on the plains, toward the headwaters of the rivers, after the streamway timber above described has ended, the plains cottonwood occurs in its characteristic "groves" about basin springs, as, for example, at Big springs, and in similar places in trans-Pecos Texas.

The Nuéces river, notwithstanding its course through the semi-arid Rio Grande plain, and its distance westward from continuous forest areas (below its cañon), is accompanied by a narrow belt of mesophytic timber of which the largest growths are the species just cited for the other streamways. Other species from the southwest, habitually only shrubs, here become small trees.

The timber of the Rio Grande valley presents three types of formation. The first is the cottonwood-willow association above the Grand cañon, with the Texas green ash (*Fraxinus Berlandieriana*), and two or three minor species in the side cañons of the Great bend. In the heavily timbered Cibolo cañon, for example, Havard reported *Populus Fremontii* four to five feet in diameter, and Texas green ash forty to fifty feet high and one to two feet in diameter. The second type, which is mainly that of the river valleys of the Nuéces and other rivers eastward, occupies the middle course of the Rio Grande below Eagle pass, but is at best a very insignificant feature. The third type occupies the valley below Rio Grande city. This is a mixture of eastern river valley species with species of the warmer Mexican region, as *Ehretia elliptica*, *Bumelia lycioides*, and several Mimoseae which have here become fair sized trees. The tropical affinities are finally marked in the lower course of the river by the appearance of an open formation of *Sabal Mexicana*, a tree twenty to thirty feet high.

Timber formations of the box cañons.—Streams which rise in or cut across the central erosion area of the Edwards plateau have worn deep and narrow channels known as box cañons, which in many cases are so sheltered and well-watered as to furnish proper conditions for typical mesophytic vegetation. Such cañons, for example, are those of the Guadalupe system and the Perdenales. The woody vegetation in these cañons, as well as the herbaceous, is that of the interior margin of the Atlantic coast plain, and yet it is to be noted how isolated these cañons are with respect to the mesophytic regions of the coast plain. In the Turtle creek cañon in Kerr county sixteen species of

trees and shrubs were found which are not a part of the typical xerophytic woody vegetation of the region, but are the commonest elements of the Atlantic coast plain forests. Herbaceous species like *Ranunculus*, *Aquilegia*, *Botrychium*, and *Dryopteris* were naturally associated in this formation. The timber growth

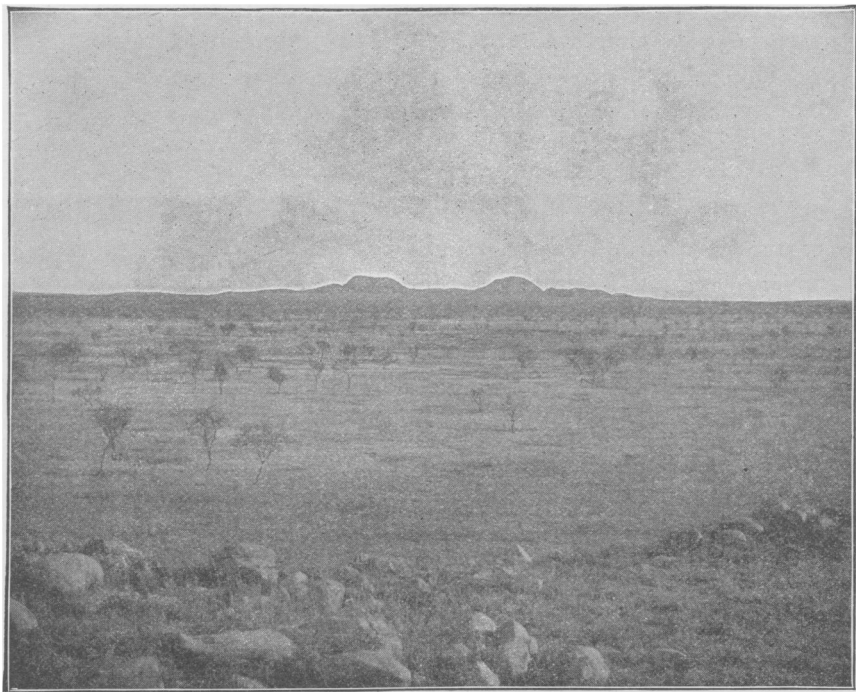


FIG. 17.—A red beds prairie, central province; the spread of mesquite is shown.—From Hill's Phys. Geog. Texas.

attains large dimensions in some of these cañons. On the Guadalupe at Kerrville a cypress stump (*Taxodium distichum*) was found measuring over four feet in diameter.

Mention has already been made of the mesophytic cañon timber of trans-Pecos Texas in connection with high mountain forests and the Rio Grande cottonwood-willow and ash timber. These cañons also furnish shelter for a few semitropical, mostly xerophytic, species common to the lower Rio Grande.

CHAPARRAL FORMATIONS.

The term chaparral as here employed is designed to carry with it not merely the idea of a shrubby formation as opposed to an arborescent one, but also a formation occupying a specific relation to ecological factors. It is a woody vegetation of warm temperate or semi-tropical requirements; adjusted to hydro-meteoric conditions wherein there is a minimum of rainfall, a dry air subject to regularly recurring movements of great velocity, and a high percentage of days of intense sunshine; related to edaphic factors in which the soil (waiving its possible great fertility or the fact that it may have had a flood débris origin) has the loose, shifting, uncohesive quality of soils formed by dry weathering and destitute of vegetable mould, if not gravelly or stony: and where the soil water level is too deep to be available for any but perennial plants with far reaching roots. Such conditions of course dwarf the growth of any woody plant subjected to them, even if it could endure them at all. Chaparral is the product of such conditions, and while characteristically shrubby, many species may under other conditions attain to arborescent size, never of course becoming large trees.

There are two general types of chaparral formation in the West Texas region, differing both floristically and ecologically. One is the chaparral of the Rio Grande plain, the other that of the trans-Pecos region. The difference between these two formations is due primarily to the climatic differences between the two provinces, and secondarily to differences in geologic and physiographic conditions.

THE RIO GRANDE CHAPARRAL.—This formation is typically a low, more or less impenetrable bush vegetation, covering continuously vast areas, and varying in height from two or three feet to ten or fifteen, according to varying ecological conditions. In the former case, the habitually shrubby and more xerophytic species prevail, for example within twenty miles of the Rio Grande from Del Rio to Laredo; in the latter, the larger species of Mimoseae form the main body of the formation, notably *Prosopis juliflora* as found from San Antonio to Kenedy. No

fewer than forty species associate in this formation, in many cases a limited area being tolerably uniformly covered by at least half of all the species (*figs. 7-10*). On the other hand, a single species constitutes almost the entire formation over extensive tracts.

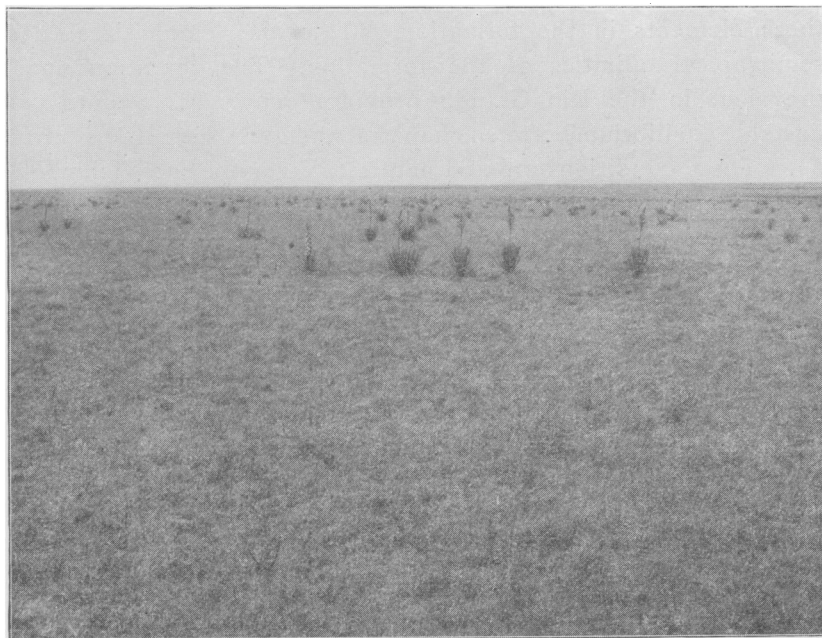


FIG. 18.—Summit of the Staked plains, 3,700 ft. alt.; grass formation with *Yucca glauca*.

On the basis of temperature, there is a distinction of species into those of semitropical and even tropical affinities and those able to endure the freezing winter temperatures of the warm temperate zone. The former occur chiefly in the lower Rio Grande country, the latter constitute the chaparral of the northern half of the plain, spreading also by some species into central Texas. Geological structure and conditions of soil act powerfully to determine the *facies* of the formation upon any given area. Thus, gravelly slopes, denuded of finer sediment, may

have a pure formation of straggling *Parkinsonia Texana*, and basalt ridges are thickly covered by a short bushy formation of *Acacia Berlandieri*. The prevalence of Mimoseae and Caesalpineae in the Rio Grande chaparral deserves special mention. No less than 30 per cent. of the number of species and a far higher percentage of actual individuals would represent the strength of these elements in the formation. This also emphasizes the semitropical affinities of the formation. The condition now prevalent in the Rio Grande province represents a state of unstable equilibrium between chaparral and grass formations (*fig. 8*). These conditions are of a nature to favor the encroachment of the chaparral. This interesting phenomenon is discussed elsewhere in this paper.

Coming next to consider individual features of the chaparral, certain conspicuous types are of special prominence.

Prosopis juliflora or *mesquite formation*.—In the Rio Grande plain this occupies the level areas of fine compact silty *débris*. Similar “mesquite flats,” as they are commonly called, are found in similar situations throughout the lower Sonoran area in Texas, but the species also occupies black prairie soils in some areas. The most massive formation of mesquite occurs on the silty *débris* plains on the northeastern border of the Rio Grande plain near San Antonio. From thence southeastward the country is a vast mesquite forest some fifty years old and fifteen to twenty feet tall. In the lower Rio Grande valley individual trees attain (for this species) gigantic size, reaching two feet in diameter and thirty-five feet in height.

Acacia Farnesiana or *huisache formation*.—This prevails especially on the low moister coast prairie clays. The species is more limited than the mesquite in both moisture and temperature requirements. Its spread has been on the coast prairie as far east as Galveston. Although cultivated as far inland as at Austin, its natural spread is not much beyond the coast country and the lower Rio Grande.

Acacia amentacea formation.—This formation is the prevalent one in the northern half of the Rio Grande province. It is the

"black chaparral," whose foliage and beans yield tons of forage. It constitutes 60 to 75 per cent. of the shrubby vegetation on many thousands of acres in Maverick, Dimmitt, and Webb counties (fig. 9.)

Acacia Wrightii formation.—This is known as "bee blossom,"



FIG. 19.—Pure formation of *Lupinus subcarnosus* at Austin; a type of prairie annual.

and "cats claw," and is especially prevalent in the northern part of the province between the Nuéces and Medina rivers. Generally it is an open formation on grass plains, and is frequently of low arborescent dimensions.

Acacia Berlandieri or *huajillo* formation.—This is a very striking vegetation occupying the basalt ridges and cones extending east and west along the northern border of the province. Farther southeast the formation has been noted on coarse gravelly ridges denuded of finer sediment. Everywhere its height scarcely exceeds three or four feet.

Parkinsonia Texana formation.—The coarse gravelly débris slopes in the Eagle pass quarter of the province are occupied by this species. It is an habitually procumbent or straggling and spreading shrub which, while occupying the ground fully, is a very diffuse covering.

Leucophyllum Texanum formation.—This species occurs in solid mass in the more arid parts of the province, especially within twenty miles of the Rio Grande on both the Texan and Mexican sides. The hairy felt covering of the foliage gives it a light tone which is very striking to the eye.

Opuntia Lindheimeri formation.—As an ecological type it is scarcely consistent to class this succulent with dwarf lignescent vegetation, and as such a type it is discussed elsewhere (see under "succulent vegetation"). But the "prickly pear" is so thoroughly a part of the bush vegetation of the Rio Grande country as to necessitate its mention here. The association of this species with mesquite has been remarked. Together they have preempted a vast amount of territory, and have introduced economic problems of no small concern, as well as interesting ecological phenomena.

On the upper course of the Rio Grande, within the Rio Grande plain, the chaparral formation assumes a more xerophytic aspect, and species of the trans-Pecos chaparral appear. A transverse section across the Rio Grande embayment from northeast to southwest would encounter this same transition to the extreme xerophytic type on the Mexican side, where the central plateau and sierra region begins, that is, at the outer rim of the embayment.

THE TRANS-PECOS CHAPARRAL.—The area covered by this type of chaparral embraces, besides trans-Pecos Texas, the north Mexican plateau and the arid lower Sonoran zone plateaus of New Mexico, Arizona, and southern California. Its northeastern extension includes the western part of the Edwards plateau and the southern slope of the Staked plains.

In the trans-Pecos region the formation occupies the cañon sides and bluffs from the Pecos westward, the rougher southern

end of the Stockton plateau, the lower slopes and foothills, the arid mountain slopes (especially in the Great bend), the dry cañons of the Great bend region, and the bolson deserts. On the whole it is more of a rock vegetation than the Rio Grande chaparral, but it also occupies the finer débris-covered slopes and bolson plains.

Compared with the Rio Grande chaparral it is in large measure floristically different. Where it contains the same species, as for example *Prosopis juliflora*, the habit is very different, being in this case dwarfed and shrubby bushes, while in the Rio Grande plain it is habitually low arborescent. The Mimoseae and Caesalpineae form less than 10 per cent. of the species, individuals occur less abundantly, and, excepting *Prosopis juliflora*, are different species from those of the Rio Grande plain. A more striking individuality as ecological types is attained in the species of this formation. This is seen in the greater abundance of the Ephedra type, the felt-covered Eurotia and Croton type, those impregnated with volatile resins, like Larrea and Flourensia, and the wand-like, fluted, thorny stems of Fouquieria (*fig. 20*).

About thirty species are recognized as more or less prominent constituents of chaparral formation of the trans-Pecos Texas. Apparently not so great a percentage of these species associate on any one area to constitute the formation, though the number of species occurring, for example, on the sides and bluff of the Pecos cañon would be little less than half the total. Considering types of the trans-Pecos chaparral formation in detail, it must suffice to point out the following.

Larrea Mexicana or *Mexican greasewood formation*.—This is by far the most notable formation of any single species. It is especially characteristic of high gravelly mesas (as about Fort Bliss, El Paso), and of the bolson deserts, extending even to highly charged alkaline soils at the center of such basins (*fig. 21*). This greasewood formation is composed of such regular open growth as to appear like plantations. The plant is a shrub with spreading top, averaging less than three feet tall. Its special

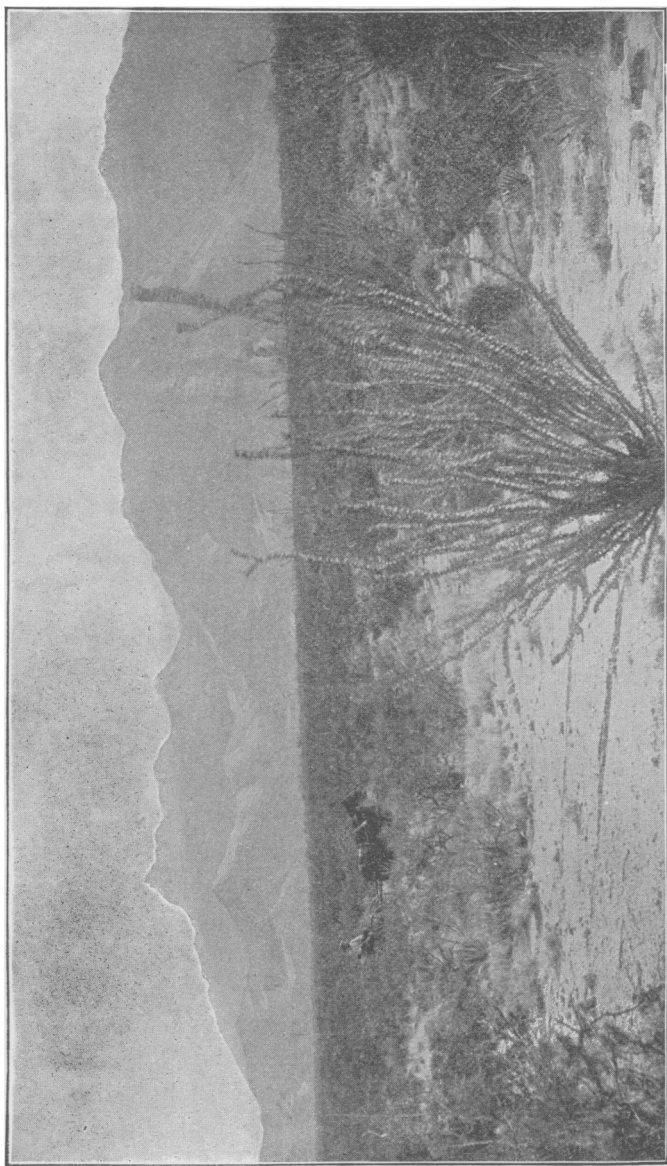


FIG. 20.—Chaparral formation on desert basin southwest of Sierra Blanca Quitman mountains; *Fouquieria splendens* in the foreground.—From Hill's Phys. Geog. Texas.

adaptation seems to lie in the great quantity of resinous matter in the leaves. The odor from this gives notice of the nearness of a greasewood formation.

THE TRANS-PECOS TYPE OF CHAPARRAL EAST OF THE PECOS.—As already noted, this chaparral spreads east of the Pecos upon the western margin of the Edwards plateau, especially its plains area, and upon the southern border of the Staked plains. The easterly extension of the more arid lower Sonoran area is indicated in this chaparral. A typical case may be cited in the vicinity of Big springs in Howard county (*fig. 16*). This is a region covered by the plains débris. The arid mesas are covered by a characteristic formation of chaparral in which not less than twenty species occur, among which are more than 50 per cent. of the characteristic trans-Pecos species.

THE RIO GRANDE CHAPARRAL IN CENTRAL TEXAS.—The chaparral of the Rio Grande plain terminates abruptly at the foot of the Balcones escarpment, where the xerophytic forest of the erosion area begins. A few species, however, mingle with the timber species, and occasionally (as in the case of *Condalia obovata*, *Zizyphus obtusifolia*, and others) forms a characteristic chaparral bush or thicket. On the grass plains of the granite country a much more pronounced encroachment of woody vegetation is taking place. As already pointed out, the mesquite has spread over most of the province. With it have gone the prickly pear and several shrubby species which together are building up a compact chaparral formation. The Rio Grande Mimoseae, except *Prosopis*, and *Caesalpineae*, and all others of the more characteristic species, do not appear in this chaparral.

FORMATIONS OF SUCCULENT OR WATER-STORAGE VEGETATION.

This third general type of formation stands out in strong contrast with the two preceding types of grass and woody vegetation. The contrast lies in the fact that whereas the preceding types have adjusted themselves to xerophytic conditions by retaining the least amount of sap-bearing tissue, this type has gone exactly to the opposite extreme. The areas occupied by

formations of this type are also in the main different from those of the other two. With few exceptions, this latter might be designated as a kind of rock vegetation, for the most significant elements are constantly associated with high, arid, stony slopes. As an ecological type the succulent vegetation is to be regarded as a more efficient adaptation to extreme aridity than the grass or woody vegetation. Consequently, it is to be found in its most typical display in the arid regions of trans-Pecos Texas.

In this discussion little account can be taken of the numerous ephemeral species like those of *Sedum*, *Talinum*, *Portulaca*, and others, but the consideration is particularly given to those more evident as features in the landscape. Of the elements composing this more conspicuous vegetation, there are three types, each forming a distinct and close genetic group. These are the Cactaceae, the Yuccaeae, and the Agaveae. A brief consideration of these may precede the discussion of the three types as associated in a single formation.

THE CACTUS VEGETATION.

A rather general survey of this group gives three types, each associated with a distinct physiographic feature: (1) the flat-jointed opuntias of the Rio Grande plain and central Texas; (2) the woody cylindrical-stemmed opuntias of the high plateau plains; and (3) the cylindrical and spherical cacti of arid stony slopes.

Opuntia Lindheimeri formation.—The prevalence of this formation in the Rio Grande plain has already been noted in discussing chaparral vegetation. The species here considered has spread beyond the Rio Grande plain to the north and east beyond the Colorado. To the east and southeast of Austin there are some extensive and typical prickly pear fields. It is present with the mesquite in the granite country in great abundance. In the Rio Grande plain the quantity of vegetation formed by this species is of almost incredible bulk. The level silty débris plains are its common habitat, but stunted formations of it also occur on arid gravelly soils, and on chalk soils

about Austin. In the valley of the Nuéces river, about midway of the plain, this *Opuntia* attains gigantic size, being said to exceed a height of ten feet. In the vast mesquite forest on the northeastern border of the Rio Grande country, the prickly pear is an undergrowth four or five feet high. These two species together are practically blocking up large tracts of pasture lands, not only changing grazing conditions, but rendering the use of such lands for agricultural purposes an expensive enterprise.

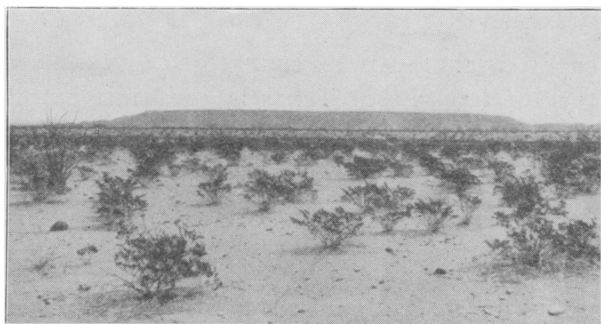


FIG. 21.—*Larrea Mexicana* (Mexican greasewood) formation; typical bolson desert of trans-Pecos Texas; *Fouquieria splendens* associated here.—Kodak view by R. T. Hill.

This *Opuntia* fruits regularly and in great quantity, and apparently is chiefly spread by means of seeds. These have been found germinating in great numbers in cow chips. The juicy fruits are eaten not only by cattle, but evidently by other mammals as well, and by birds.

THE CYLINDRICAL OPUNTIAS.—These are chiefly plants of the high plains westward, *Opuntia frutescens* being an exception. This species is part of the chaparral of the Rio Grande plain and the adjacent provinces northward. It occurs especially in association with spreading shrubby species by which it partially supports its slender stems, and together forming well-defended clumps of chaparral, from which there is a gradual encroachment upon the grass formation. The presence of the *Opuntia* prevents the shrubs from being eaten back by cattle. *Opuntia arborescens*

is conspicuous on the high grass plains of the Stockton plateau and westward. It also occurs east of the Pecos at the foot of the Staked plains, and to a less degree on the summit of the south half of the plains. At the base of the plains in Borden county it is very common and of large size, reaching seven and eight feet in height. This *Opuntia* does not occur as a continuous formation, but at intervals serving rather to punctuate the grassy landscape. This is always noted by travelers who observe the landscape of the trans-Pecos grass plains traversed by the railways.

THE BROAD CYLINDRICAL AND SPHERICAL CACTI occur upon arid stony slopes of trans-Pecos Texas as the most extreme type. These associate with *Agaveae* and *Yuccaeae* to make the type of formation to be discussed subsequently. East of the Pecos, on stony hillsides, rock bluffs, and even on coarser gravel ridges, cespitose species of *Cereus* occur, often (as in the case of *C. caespitosus*) forming patches from a few yards to many rods in diameter, as on broken granite slopes in Llano county.

THE YUCCA VEGETATION.

The prominent yucca vegetation of the so-called "yucca belts" is a part of a mixed formation to be considered presently. Independently of this, certain areas of yucca vegetation are to be noted (*fig. 24*). First, the occurrence of *Yucca Treculeana* in the lower Rio Grande and Gulf coast region, where it is said to form "open stunted forests." Again on the cañon sides in the central erosion area the same species (apparently) forms a conspicuous feature of the cañon flora. Second, the constant occurrence of *Yucca rupicola* upon the talus débris of slopes leading down from crumbling limestone formations. The formation, of which this is but an element, is one of the most distinct minor formations of the cretaceous areas east of the Pecos. Third, *Yucca angustifolia* is particularly characteristic of the Staked plains region. Here it follows the gentle slopes about shallow basins or the wave-like undulations where the soil is looser and more sandy. Fourth, *Nolina* formations on the Rio Grande

plain below the Balcones escarpment, and at many places on stony slopes as far east as the Colorado. The great tufts of this so-called bunch grass form the most conspicuous vegetation on the finer débris below the yucca belt in the Rio Grande plain.

THE AGAVE VEGETATION.

In addition to species of the Agaveae which associate in the mixed cactus-yucca-agave formation to be next described, two species require notice. *Agave Wislizeni*, or "Texas mescal," is a mountain species (apparently upper Sonoran to Transition) occurring (according to Dr. Havard) in all the mountains of western Texas, and formerly much used for food, beverage, and medicine. *Agave Americana*, or "Mexican maguey," enters the Texas region in the lower Rio Grande plain, and two or three more insignificant species are also present.

MIXED CACTUS, YUCCA, AND AGAVE FORMATION OF ARID STONY SLOPES.

While the trans-Pecos region possesses more or less of each of the three types included in the above named formation, in most of its physiographic provinces a little investigation shows that in the main the three are found upon one type of physiographic structure, either more or less equally represented, or one type predominating. In traversing the high grass plains of the Stockton plateau and westward it is noticed that in approaching the crest of one of the broad undulations, or any relief feature notably above the plains level, a unique yucca vegetation sets in, to be followed again presently by other stretches of grass plain. Where the margin of the plain rises up into the bordering foothills, there again is the yucca vegetation. Again, on the rim of the enclosed bolson basins this formation is present, and finally on many of the gentler slopes of the mountains (especially those with timberless arid slopes) the yucca vegetation is present as the chief vegetation feature. This is the apparent condition seen at a distance, and sometimes the Yuccae are alone in the formation. But a nearer look commonly reveals the less conspicuous cactus and agave members of the association (*fig. 22*). In all the physiographic features cited, practically the same

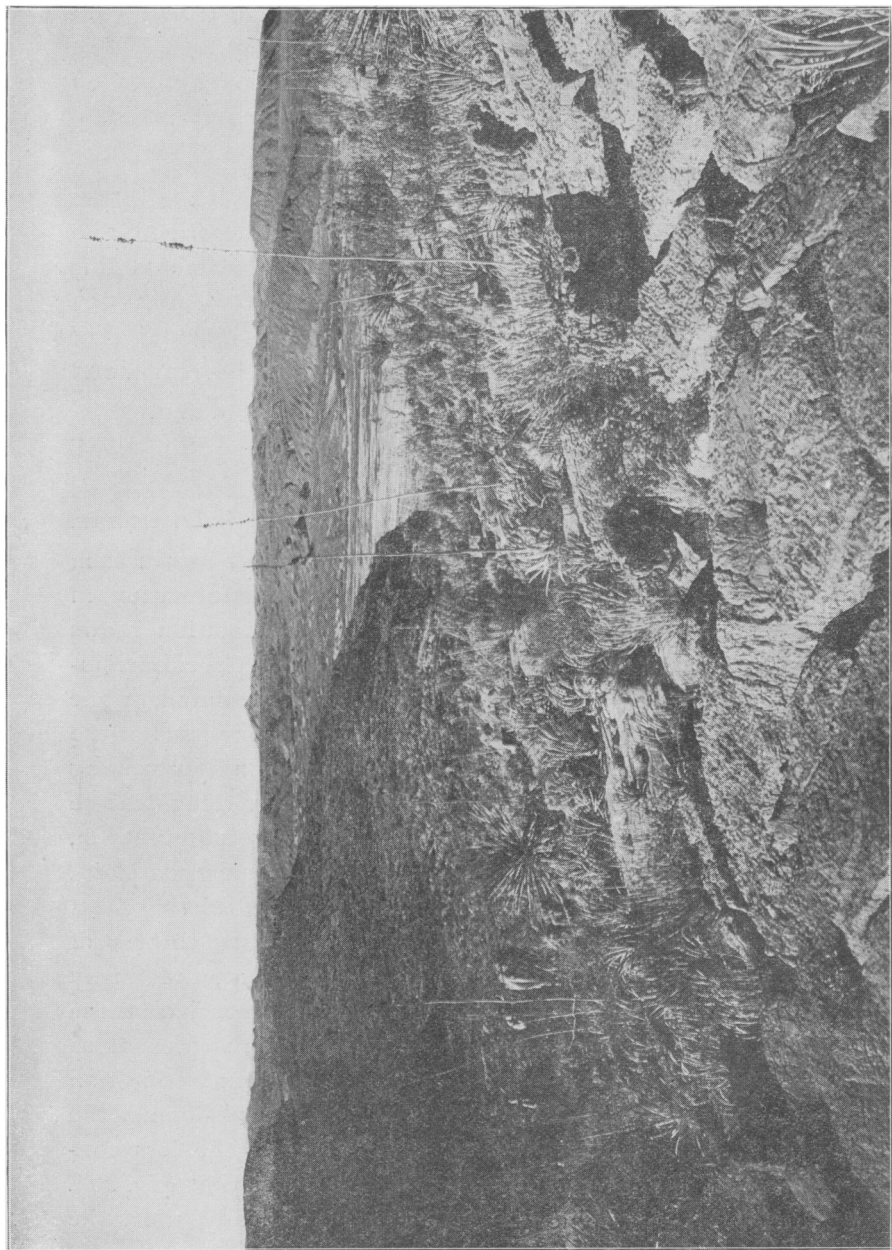


FIG. 22.—Yucca-agave-cactus formation of stony slopes; mountains of the Great bend of the Rio Grande, in trans-Pecos Texas.—Photograph by R. T. Hill.

ecological conditions prevail. In the wearing away of the mountains in this dry climate the débris is carried downward to fill the intervening basins. The finer débris being carried nearest the basin center, on the slopes at the outer rim of the basin lies the coarser débris, an unconformable mass of coarser or finer stony talus. This talus débris may extend far up the slopes of mountains, which receive but a few inches of rainfall annually, especially those in the Great bend, and thus carry the formation of cactus, yucca, and agave with it. These "yucca belts," as Mr. Hill calls them, when projected upon a map appear as marginal lines of basins and to encircle the various mass elevations. The formation extends even to the east of the Pecos cañon along the coarse débris from the Balcones escarpment. The abundant occurrence of *Yucca Treculeana* and several species of cacti on the timberless cañon sides as far east as the Colorado may be regarded as an extension of the same formation.

As to the prominence of the several types in the formation, as already stated, viewed from a distance the yucca vegetation seems the only prominent one. It is in reality so only in some instances. In other cases other types play the chief rôle, so that several variations exist, as illustrated by the following:

Open forest-like formations of the palmo or Yucca macrocarpa.—This largest of our yuccas is very abundant in the Great bend region, covering the long arid slopes with an open formation of yucca trees "with caudex ten to twenty feet high and one to two feet in diameter" (Havard).

Lechuguilla (Agave heteracantha) and sotol (Dasylirion Texanum) formation.—This is a very characteristic formation of very rough stony slopes in which the lechuguilla forms a most obnoxious feature because of its aggressive short bayonet-like leaves. This formation is very common as far east as the Nuéces cañon.

Formations in which globular and cylindrical cacti predominate.—These include several species of *Mamillaria* (among them forms called "devils pin cushion"), *Cereus* (notably the strawberry cactus, *C. stramineus*), *Echinocactus* (especially the "Turk's head," *E. longihamatus*), and *Anhalonium*. Such formations

indicate about the ultimate point of extreme exposure to intense light, burning midday and chilling midnight temperatures, and moistureless air and soil.

There is still another and very striking species associated with the cactus-yucca-agave formation, especially on the most arid stony mesas and slopes where cacti predominate. This is *Fouquieria splendens*. Its slender, thorny, wand-like stems arise in small groups from the surface of the ground to the height of five to eight feet, bearing leaves only in a tuft at the apex. It is as if the most arid spots had been located and marked out by this plant (*fig. 20*).

ROCK VEGETATION OF CRYPTOGAMOUS PLANTS.

The formation of succulent vegetation might be designated, on the whole, rock vegetation, occurring as it does either upon stony talus or on cañon bluffs. Certainly many succulents not mentioned in the discussion are characteristic rock plants, but the attempt here is to select types of formation which in a peculiar or conspicuous way constitute the characteristic vegetation. The xerophytic cryptogamous plants constitute such a vegetation. They are a rock vegetation either because they occur upon a bare rock substratum or because they inhabit clefts or fissures in the rocks, or dry rock ledges. The former play an important rôle in disintegrating solid rock, as the granitic lichens, or in promoting the accumulation of a matrix of organic material upon barren surfaces, as the Cyanophyceae on bare chalk or compact limestone débris. Throughout the central Texas Cretaceous areas the occurrence of these low plants is very noteworthy. They consist of a species of *Nostoc* which occurs in curled, crumpled masses after rains or foggy weather, literally covering the ground; a mat-forming *Scytonema*; and several matted, leathery lichens.

The so-called rock ferns are ecologically the most noteworthy elements of the vegetation of rock fissures and ledges. The several genera and numerous species of ferns constituting this xerophytic group are associated with the Sonoran climatic

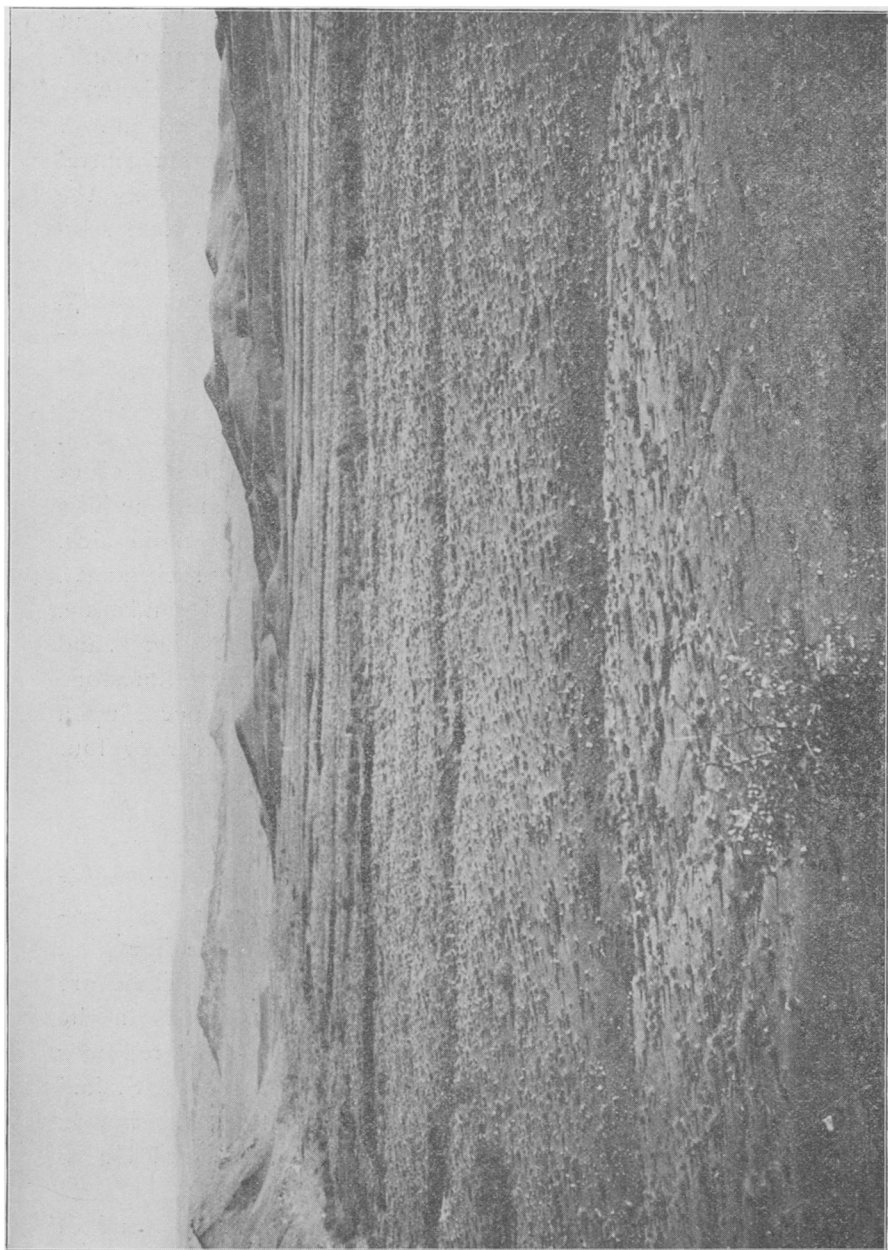


FIG. 23.—A dead "bunch-grass" desert, adobe soil; Tomillo desert, trans-Pecos Texas.— Photograph by R. T. Hill.

conditions of the southwest, and occur not only throughout that area, but over its southward extension along the continental axis south of the equator. Their distribution in the west Texas region coincides with the areas of escarpment, and of cañon erosion. They occur, for example, throughout the central erosion area. Aside from the various means of adapting the vegetative plant to xerophytic conditions, the ecological relations of this group of ferns has not been much studied.

Two additional important species are to be noted, namely, *Selaginella lepidophylla* (a "resurrection" plant) of the trans-Pecos region, but also extending eastward on limestone bluffs and knobs to the Frio river; and *Selaginella rupestris* (the forms still so designated) is especially abundant in the granite area, but it appears to be in all of the mountainous or hilly areas of west Texas (on dry gravel ridges at Austin), on limestone hills on the upper Nuéces cañon, and in trans-Pecos mountains. Several extremely xerophytic mosses are essentially rock plants. Some form close velvety masses on granite and sandstone. Other species occur with *Selaginella rupestris*, and *Scytonema*, and lichen mats on the dry gravel ridges and on compact limestone débris. Several xerophytic species of liverworts occur upon granite fissures and upon gravelly soils, notably three or four species of Ricciaceae.

HALOPHYTIC VEGETATION.

The areas in the west Texas region in which the soil is impregnated with alkali sufficient to affect the vegetation covering are rather large and widely distributed, and have been but little investigated from a botanical point of view. There are included here in general (1) the gulf coast, (2) basins in the lower Rio Grande plain, (3) the gypsum beds of the red beds country, (4) the alkali basins of the western side of the Staked plains, (5) the Pecos valley or Toyah basin, (6) the bolson basins of trans-Pecos Texas of which the Howard and Hueco bolsons are the largest.

From Dr. Havard's description of the "Pecos flats" and of

Salt lake basin (the Howard basin), it appears that the two types of vegetation on these alkaline flats are grass and chaparral formations. He says (*loc. cit.*, p. 465) "the prevalent grass of the Pecos flats and often the only kind is *Sporobolus airoides*, with erect culm one to three feet high, and loose open panicle. It is distinctly salt to the taste," etc. "On alkaline soils occur the fleshy chenopods *Suaeda suffruticosa* and *S. depressa*, and *Spirostachys occidentalis*." Of the Howard basin he says (p. 497) "the smooth, broad beach of the lakes (occupying the center of this basin) more or less incrustated with alkali is absolutely bare. Here and there low sand hillocks are covered with *Spirostachys occidentalis*, *Larrea Mexicana*, and *Frankenia Jamesii*." The salt grasses of the northern extremity of the basin consist mostly of *Sporobolus airoides* and *S. Wrightii*.

Detailed information of the vegetation of alkaline basins or of the Gulf coast within the region here considered is not sufficient to warrant further discussion.

CHANGES IN PREVALENT FORMATIONS DUE TO AGENCIES OF CIVILIZATION OR OTHER CAUSES.

The equilibrium established upon the vegetation of the west Texas region as a resultant of all the forces playing upon it has been destroyed by the introduction of new forces chiefly due to human agency. As a consequence, the vegetation of the region is undergoing some profound changes. Under the reign of equilibrium the trend was decidedly toward the establishment of solid grass formations, thus making the region one of open grass prairies and plains. The present trend is decidedly toward the establishment of woody vegetation, either shrubby or dwarfed arborescent, with a coincident driving out of sun-loving species (especially grasses) and favoring of the shade-loving ones.

Other changes not in the direction of establishing a woody vegetation are taking place. For example, in the constitution of the grass formations Jared G. Smith observes (Bull. 16, U. S. Div. Agrost., p. 28) "before the ranges were overgrazed, the grasses of the red prairies were largely blue stems or sage

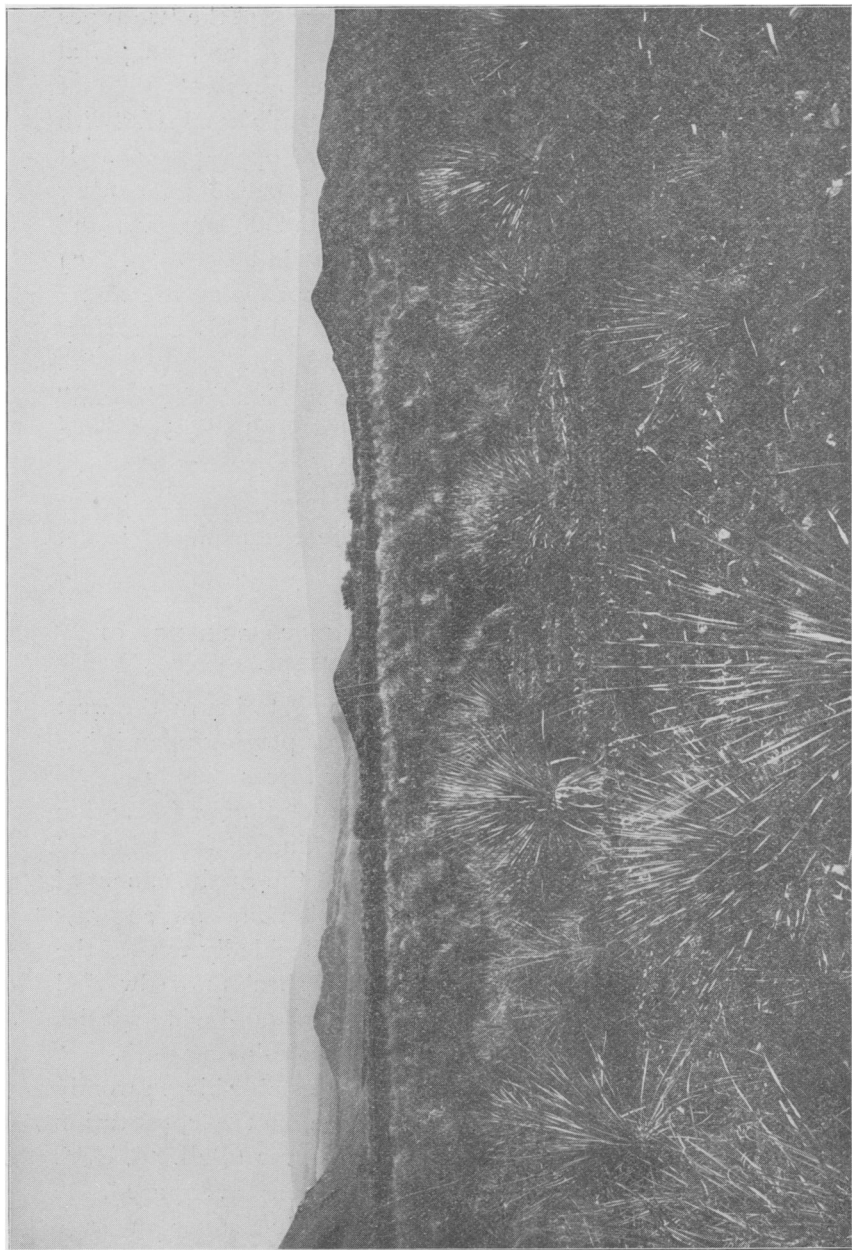


FIG. 24.—Yucca formation on foothills of Chisos mountains, trans-Pecos Texas; Yucca ("palmella") and sotol (*Dasylirion Texanum*); oak in the background probably *Q. Emoryi*.

grasses (*Andropogon*), often as high as a horse's back. After pasturing and subsequent trampling and hardening of the soil the dog grasses or needle grasses took the whole country. After further overstocking and trampling the needle grasses were driven out and the mesquite grasses (*Hilaria* and *Bulbilis*) became the most prominent species."

There is a further strong tendency toward the establishment of a weed vegetation to the disadvantage of what may be called the native vegetation. Such for example are *Gutierrezia Texana* and *Croton Texensis*.

Regarding the establishment of woody vegetation, it is the unanimous testimony of men of long observation that most of the chaparral and mesquite covered country was formerly open grass prairie. This applied to the Rio Grande plain, as well as to the mesquite flats of the central provinces. Illustrations are everywhere at hand. At Austin, for example, many black land pastures have within a few years become covered by a perfect jungle of mesquite.

Apparently under the open prairie régime the equilibrium was maintained by more or less regular recurrence of prairie fires. This, of course, is by no means a new idea, but the strength of it lies in the fact that the grass vegetation was tolerant of fires and the woody vegetation was not. It was only after weakening the grass floor by heavy pasturing and ceasing to ward off the encroaching species by fire that the latter invaded the grass lands. Once the equilibrium was destroyed everything conspired to hasten the encroachment of chaparral—droughts, pasturing, trampling, seed scattering, and so on. As Smith pointed out, a mesquite tree once established became a center of infection in offering shelter for shrubby plants and shade-loving grasses, driving out the native prairie grasses. In brief, the efforts to exploit the wealth of grass lands for profit, namely stock raising, have been the main agency in transforming them rapidly into lands covered by a totally different and far less valuable vegetation.

Another economic question arises from artificial change of

plant formations, though exactly the reverse of the preceding discussion, namely, in destroying the woody vegetation of certain areas. The great demand for charcoal, fuel, posts, and rough construction timber, and the desire to secure small patches for temporary cultivation are resulting in a rapid removal of the xerophytic timber vegetation and the cañon timber from the hill country of the Edward's plateau. This brings up the question of the relation of this timber vegetation to the water supply, to soil erosion, and to destructive floods. In some cases, at least, this formation is succeeded by the rock vegetation and the adobe vegetation of the Cretaceous areas, which establish themselves as a result of denudation by erosion which follows removal of the timber covering.

SUMMARY.

1. By reason of its geographic extent and position and of its relief, the west Texas region possesses floral elements ranging in their temperature relation from tropical to transition.

2. In its climatic relations the region falls partly under the eastern or Atlantic type (Gulf type, Great plains type), and partly under the Pacific (Yuma type, Mexican type). This brings about great diversity of vegetation in the moisture relation.

3. This region is the meeting ground of the following floral elements: (1) the Gulf neotropical; (2) the Mexican semitropical; (3) the Austro-riparian and Carolinian; (4) the Great plains upper Sonoran; (5) the north central prairie region; (6) the Rocky mountain; (7) the south plateau (of the Rocky mountains) upper Sonoran; (8) the arid plateau and bolson desert lower Sonoran.

4. The physiographic and geologic provinces coincide in general with vegetation provinces distinguished by characteristic vegetation formations.

5. The flora of the entire region is one of xerophytic aspect, but of several grades from semi-arid to extremely arid. Broad streamways and cañons and high mountains carry mesophytic vegetation into the heart of the region.

6. Annuals whose vegetation period covers only a few weeks exist generally in pure formation in all parts of the region having a constant annual recurrence of temperature and moisture conditions suited to the species in question. Thus the plains from the lower Rio Grande to the Red river and northward may possess successively the same ephemeral but extremely brilliant formations.

7. The vegetation native to the region before the coming of civilization is undergoing profound changes as a result of disturbed equilibrium. This is no doubt exterminating certain species, especially grasses. The chief results of the changes appear in establishing a woody or weed vegetation, and in the denudation of the hill country.

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